How to Build a Stable VFO

VFOs (variable frequency oscillators) are used in receivers, transmitters and signal generators, as well as in various other pieces of test equipment. Frequency stability is an objective that all designers pursue. A VFO that exhibits frequency drift can spoil the performance of an otherwise good circuit.

For example, the greater the overall selectivity of a receiver the more pronounced the effects of VFO instability. This is because it becomes a tedious task of keeping the receiver tuned so that the desired signal remains within the narrow IF (intermediate frequency) passband.

Types of Drift

We have what is called short-term drift and long-term drift. The latter is perhaps the most annoying of the two conditions because the equipment stability never seems to settle down to permit the main tuning dial to be left at a given setting.

An ideal VFO could be turned on, set to the selected frequency and never readjusted until you become interested in a new frequency. This is seldom possible without incorporating a PLL (phase-locked loop) or synthesizer. Most LC (inductance/capacitance) tuned oscillators have some drift, but it can be minimized to lessen the need for frequent retuning of the system.

Drift is caused by heat. Internal heating from RF and DC currents cause changes in component capacitance and resistance, and this results in a change of oscillator frequency. This is true of solid state or tube types of circuits. Variations in ambient temperature around the VFO components also cause drift. The operating frequency is affected also by dampness (humidity).

You can see from this that we must deal with numerous conditions that can affect the circuit performance. Stray, unwanted RF energy from other parts of a transmitter circuit may also enter the VFO circuit and cause abrupt changes in oscillator frequency. Good shielding of the VFO circuit, along with filtering of the DC leads that enter the VFO compartment, normally prevent this type of circuit disruption.

Short-term drift is caused by the initial heating of the transistor junctions, along with internal heating of the VFO capacitors. Generally, this form of drift ceases within five minutes of circuit turn-on. It is, therefore, not a matter for deep concern among amateurs and experimenters. An acceptable VFO may have a short-term drift that amounts to, say, 300 Hz (0.3 kHz).

This form of drift can be reduced by using low operating voltages and relying on small amplifier stages after the oscillator for building up the output power of the overall VFO circuit. The lower the operating voltage, the less the DC and RF current that flows through the components. For example, a transistor that would normally be operated from 12 volts DC will give better service in a VFO if the operating potential is reduced to six volts, regulated. This can be done with a Zener diode.

Also, the greater the internal surface area of the VFO fixed-value capacitors the faster the VFO will settle down. This is because the RF current flows over a larger area and results in less heating. This can be achieved simply by using two capacitors in parallel at each key circuit point. By way of an illustration, if the circuit calls for a 100-pF NPO capacitor, use two 50-pF capacitors in parallel. In a like manner, 1/4 or 1/2 W resistors are better than 1/8 W units for biasing the oscillator. The smaller resistors can exhibit resistance changes from internal heating caused by DC-current flow.

Very light coupling between the VFO tuned circuit and the oscillator transistor helps greatly to minimize short and long term drift. A good rule of thumb is to use the

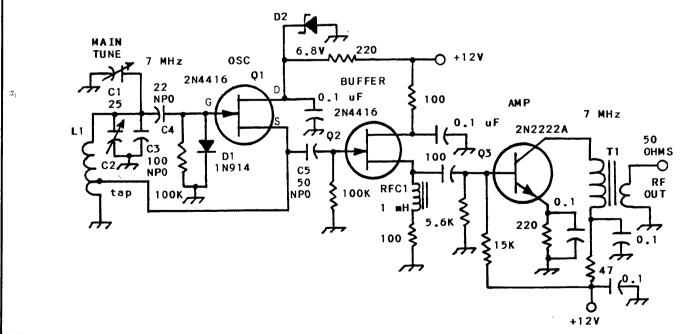


Figure 1 -- Schematic diagram of a practical 7-MHz VFO. Fixed-value capacitors are disc ceramic unless otherwise noted. NPO signifies temperature-stable ceramic capacitors. C1 is a double-bearing air variable for use with a vernier drive. C2 is a 25-pF NPO ceramic trimmer or air variable trimmer. D2 is a 400-mW Zener diode. A miniature 1-mH RF choke is used for RFC1. T1 has a primary winding of 15 turns of no. 26 enamel wire on an Amidon Assoc. FT-37-43 ferrite toroid. The secondary winding has four turns (see text) of no. 26 enamel wire. Many of the parts for this and other experimenter's circuits are available from Oak Hills Research (KE8KL), 20879 Madison St., Big Rapids, MI 49307. Send a large SASE with \$.50 postage for a catalog.

smallest value of coupling capacitor that is consistent with reliable oscillator starting. This also helps to preserve the Q of the tuned circuit (reduced loading), which enhances the purity of the VFO output waveform. The higher the Q the lower the wide-band noise from an oscillator.

Choices for Fixed and Variable Capacitors

Some equipment builders like to use silver-mica capacitors in a VFO. These were among the better stable capacitors in the old days of radio, but newer and better types are currently available. My first choice is the NPO (zero temperature coefficient) ceramic capacitor. My second choice for circuits that operate up to 10 MHz is the polystyrene capacitor.

Silver-micas are quite unpredictable with respect to their temperature stability. We might select four 150-pF silver-mica capacitors from a given production run, only to find that one is temperature-stable, while one has a positive drift trait and the remaining two have a negative drift profile. You can, however, hand pick your silver-micas through experimentation (tedious) until you have a stable VFO.

Variable capacitors should have a bearing (preferably the ball type) at each end of the rotor. The capacitor should turn freely to prevent undue stress and lumpy tuning. The vernier drive used with the tuning capacitor must be free of backlash. Variable capacitors with aluminum plates are not good choices for VFOs: the metal expands and contracts with temperature changes, and this causes drift. Plated brass vanes are best for VFO service.

VFO Coils

Whenever possible you should avoid using a coil that has a ferrite or powdered-iron core. This core material is affected by temperature changes, and this can cause severe instability. An air-wound coil (glued to a ceramic form) is my preference when there is ample space for it. My second choice is a slug-tuned ceramic form that has suitable core material for the operating frequency.

The wrong core substance can ruin the Q of the coil and degrade the oscillator performance. If you use a slug-tuned form, try to set up the circuit so that very little core material is inserted into the coil winding. The less core you use the better the stability.

Toroid cores should be avoided whenever possible. This is because the entire coil is wrapped around the powdered-iron core. If you do use a toroid, stick with no. 6 (yellow coding) material for the MF and HF ranges. The no. 6 core (sold by Amidon Assoc.) is the most stable of the HF group. The completed toroid coil should be coated with at least two

layers of Polystyrene Q Dope (General Cement) to keep the turns firmly in place.

A Typical Circuit and Some Tips

Figure 1 shows an example of a practical VFO. I suggest you duplicate this circuit for the purpose of learning how VFOs operațe. If you have access to a frequency counter you may test the circuit for stability.

L1 in Figure 1 is a 4.2 μ H inductor. C2 is a trimmer capacitor that is used to adjust the tuning range and calibrate the VFO dial. C1 is the main tuning capacitor. Note that C3, C4 and C5 are temperature-stable NPO capacitors. Trimmer C2 should be an NPO ceramic trimmer.

D1 stabilizes the gate bias of Q1 to aid the frequency stability. Although I have specified a 2N4416 JFET at Q1 and Q2 (best choice), you may use MPF102s for the sake of experimentation. Output from Q1 is buffered (isolated from Q3) by source follower Q2. It has no gain. Its output is roughly 0.9 the signal applied to its gate, which is the rule for source or cathode followers.

Q3 is a broadband amplifier that boosts the output from Q2. The secondary winding of T1 may be changed to increase or decrease the impedance ratio of the transformer. More turns will allow the circuit to match into higher impedances (50-ohms is specified in Figure 1).

The tap on L1 is for feedback, which is necessary for oscillation. Typically, the feedback power is 1/4 the oscillator output power. The L1 tap is made at a point that is 25 percent of the total L1 turns (tap up the grounded end). Use care to prevent shorting adjacent coil turns when making the tap. Shorted turns will ruin the Q of the coil.

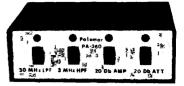
Closing Remarks

The circuit in Figure 1 may be changed for various frequencies in the MF or HF range. For example, if you want to use the circuit on 3.5 MHz, merely double the values of L1 and C1 through C5. For 20-meter use, halve the component values. These changes will be approximate for the ranges specified. You will need to experiment with the parts values to cover the exact tuning range you desire.

The hints I have provided in this article may be applied also to factory-made VFOs if you encounter a stability problem. Total drift (an hour or more) should not exceed, say, 600 Hz from a cold start to the time of stabilization. Information about winding coils for a particular inductance is available in *The ARRL Electronics Data Book* and *The ARRL Handbook*.

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